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April 8, 1969 JAMES E. WEBB 3,437,959

ADMINISTRATOR OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

HELICAL COAXIAL RESONATOR RF FILTER

Filed Jan. 20, 1966

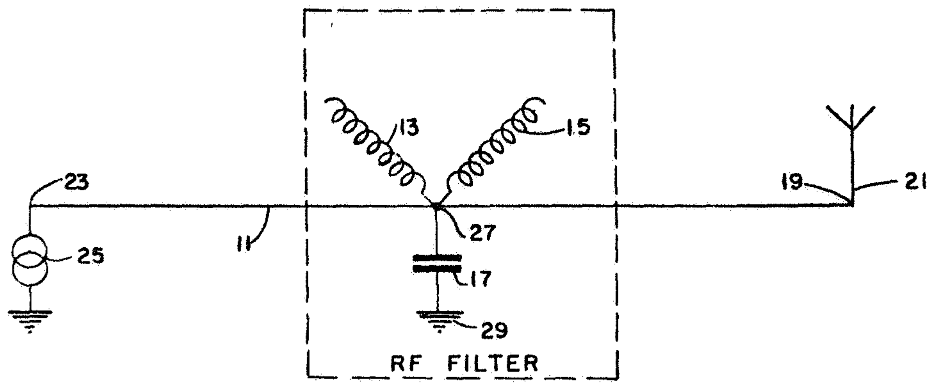

FIG. 1.

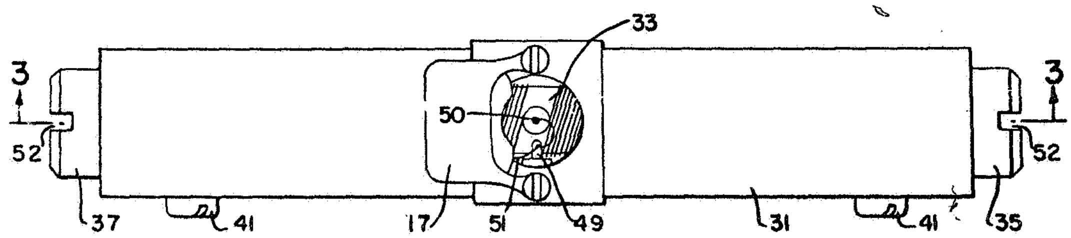

FIG. 2.

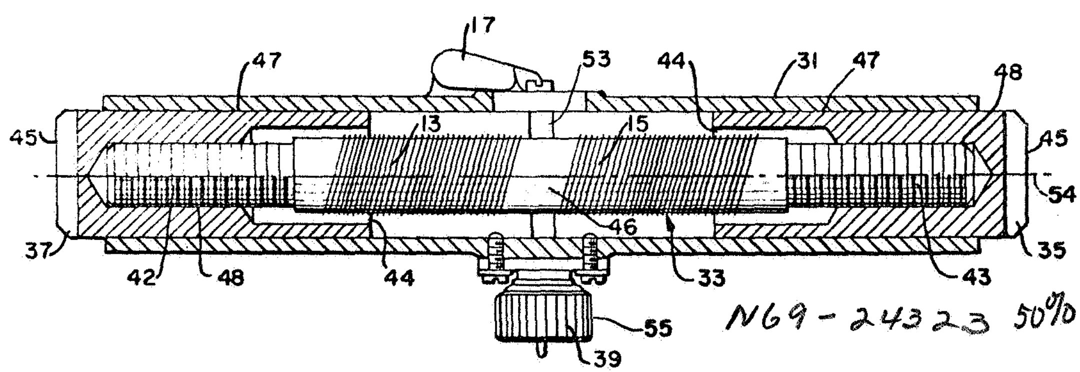

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FIG. 3.

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HELICAL COAXIAL RESONATOR RF FILTER

James E. Webb, Administrator of the National Aeronautics and Space Administration, with respect to an invention of Myron Walter Maxwell, Dayton, N.J.

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Int. Cl. H03j 3/22, 3/26; H01p 7/04
U.S. Cl. 333—73 5 Claims

The invention described herein may be manufactured and used by and for the government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to electronic filtering and more particularly to RF filtering.

RF filtering is utilized in electronic transmission systems to pass signals in a desired frequency range and reject signals outside of that frequency range. In the past this has been done with complex electronic networks. These prior art systems generally consisted of a plurality of resistors, capacitors, and inductors in ladder types of configurations. These systems have proven to be very satifactory for low RF applications. However, as RF has moved into the megacycle ranges and above, these systems have been increasingly unable to fulfill filtering requirements. At high RF frequencies the inductors utilized in these filter networks are very small and hence are difficult to design and construct. Even though design and construction problems can be overcome for single signal environments, they become increasingly difficult to solve when the transmission line carries both a desired RF signal and closely spaced undesired signals. Adding to this the problems raised by placing a filter network in a changing environment, such as on a spacecraft subject to thermal changes as well as shock and vibration, the design of the filter becomes almost impossible.

In order to alleviate some of the foregoing problems the prior art has developed coaxial cavity resonators which operate at higher RF frequencies than conventional filter networks and provide very reliable and simple filtering systems. However, it has been found that when a transmission line has several signals of high magnitude and relatively close frequency spacing even a coaxial cavity resonator does not provide a high pass filter at the desired signal frequency while it filters out signals of undesired frequencies.

A spacecraft is limited as to the size and weight of components that can be used on a craft. Consequently it is desirable to use one antenna for both the transmission and the reception of RF, and preferably that antenna is designed in accordance with the frequency of the signals transmitted or received. Therefore, to obtain the maximum benefit from that one antenna, the transmission and reception signal frequencies must be closely spaced. As noted, however, when the transmission and reception signal frequencies are so closely spaced it becomes difficult to pass a signal at one of these frequencies and reject signals at another frequency. This situation becomes even more critical when two or more sets of closely spaced transmission and reception frequencies are used. Consequently, it is desired to obtain a filter system which will pass a signal of the desired frequency and reject other

signals closely spaced thereto. Further, it is desired to obtain a filter having a high Q and a low insertion loss at the desired frequency thereby preserving the amplitude of the desired frequency signal while rejecting undesired signals.

Therefore, an object of the present invention is the provision of an improved method for filtering a signal or signals of undesired frequency while preserving a signal of desired frequency.

Another object is to provide a method of passing a desired RF frequency signal and rejecting undesired RF frequency signals closely spaced to the desired signal.

It is still another object of the invention to provide simple, compact, and light weight apparatus for rejecting signals of undesired frequencies which are closely spaced to signals of a desired frequency.

A further object of the invention is the provision of a helically wound coaxial resonator having a high Q and a low insertion loss which operates at RF and is adapted for connection in shunt to an RF transmission line.

The foregoing and other objects of the invention are accomplished by the provision of a novel helically wound coaxial resonator connected as a shunt stub to a coaxial transmission line. The helix is housed in a casing and has one end connected to the center conductor of the transmission line while the other end is open circuited. A capacitor is connected between the center conductor and ground to cancel out residual shunt reactance and an adjustable tuning slug is used to determine the filter's resonant frequency and provide a high conductance path to signals at that resonant frequency. However, other signals which are merely close to this frequency are subject to a low conductance path. Consequently, by connecting the apparatus in a shunt relationship to a coaxial transmission line, the apparatus operates to shunt out the resonant frequency while having little or no effect upon frequencies near the resonant frequency. By making the resonant frequency the undersired signal frequency a method is provided to shunt out the undersired signal. If two or more frequencies are desired to be shunted a plurality of helically wound cores are utilized.

It will be appreciated that the foregoing system provides a simple method of eliminating signals of undesired frequency from a coaxial transmission line by shunting them through a novel apparatus which is used as a quarter wave length shunt stub resonating at the undesired frequency. However, due to the very narrow pass band at the resonant frequency signals outside of this band will not be shunted.

Other objects and many attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawing wherein:

FIG. 1 is a line diagram of a preferred embodiment of the invention utilized to shunt two RF frequencies;

FIG. 2 is a schematic diagram of a preferred embodiment of the apparatus of the invention utilized to perform the functions of the structure illustrated by the line diagram of FIG. 1; and

FIG. 3 is a partial section of the device illustrated in FIG. 2 taken along the lines 3—3.

FIG. 1 is a line diagram illustrating the invention as it is utilized to shunt two RF frequencies. The structure illustrated is comprised of a coaxial transmission line's center conductor **11**, two helical windings **13** and **15**, and a capacitor **17**. One end **19** of the center conductor **11** is connected to an antenna **21** and the other end **23** is connected to a receiver **25**. Interposed between receiver **23** and antenna **21**, connected to the coax transmission line **11** is the RF filter of this invention, shown within

the dashed lines of FIG. 1. Schematically, one end of each of the two helical windings **13** and **15** is connected to the center conductor **11** at a point **27** between the antenna **21** and the receiver **25**. One terminal of the capacitor **17** is also connected at point **27**. The other end of the capacitor **17** is connected to ground **29**. The opposite ends of the helical windings are open circuited.

The embodiment of FIGS. 2 and 3 illustrate the preferred configuration. To connect the applicant's filter to the transmission line to be affected, a standard T connector (not shown) may be inserted into the transmission line, one leg of the T being connected to the coax connector **39** of the applicant's device. When the antenna **21** is utilized for both the transmission line and the reception of electronic signals all of these signals will propagate along the coaxial transmission line's center conductor. When these signals are very close in frequency it is difficult to pass the desired signal to the receiver and reject other undesired signals. In this preferred embodiment of the invention, for example, it is intended that the antenna receive one desired signal and also transmit two transmission signals both of which are close to the frequency of the received signal. In the past it has been extremely difficult to direct the desired signal to the receiver without passing some of the transmission signals to the receiver as well. The present invention, however, prohibits these undesired transmission signals from reaching the receiver by shunting signals at undesired frequencies but not shunting signals at the desired frequency. Specifically, as hereinafter described, the two helical windings **13** and **15** are wound about a core contained in a metal casing thereby forming the coaxial resonators. Slugs are provided to tune the resonators to the two undesirable transmission frequencies. In addition, the capacitor **17** cancels out residual shunt reactance at the desired frequency to minimize the shunt conductance and thus minimize the insertion loss. Hence, as in the above example, merely by the step of shunting undesirable frequencies rather than blocking them as in the past, the invention provides a simple method of eliminating signals of known undesired frequency. Moreover, in accordance with the structural aspects of the invention a simple helical resonator is connected to the transmission line to shunt the undesired frequencies.

In FIGS. 2 and 3 the invention is illustrated as comprising a tubular casing **31**, an inner core **33**, two tuning slugs **35** and **37**, a capacitor **17**, and a coaxial connector **39**. Preferably the core **33** comprises a cylindrical length of plastic rod stock having an inner section **46** and threaded ends **42** and **43**. The inner section is of slightly larger diameter than the ends **42** and **43** but is of sufficiently small size to fit inside of the tubular casing **31**. Preferably the tubular casing is formed of aluminum. The helical windings **13** and **15** are wound about the inner section **46** starting at the center and winding toward the ends of the core.

The tuning slugs **35** and **37** comprise tubular cap structures of dielectric material having an open end **44**, a closed end **45**, and an outer diameter **47**. The opening at end **44** is circular and of sufficient diameter to fit over the inner section of the core **33**. This opening reduces in diameter to a smaller opening **48** at a point approximately one third of the way along the tuning slug's longitudinal axis. This smaller section **48** is threaded internally to screw snugly onto the ends **42** and **43** of the core **33**. Further, the outer diameter **47** is of appropriate size to fit snugly into the tubular casing **31**.

The cylindrical core **33**, with the tuning slugs on each end thereof, is mounted in the tubular casing **31** with the longitudinal axes of these elements being coaxial. The tuning slugs **35** and **37** extend beyond the ends of the casing and have slots **52** therein to provide a means for adjusting tuning by moving the slugs along the longitudinal axis **54** of the core **33**. A pair of self tapping screws **41** are aligned with the tuning slugs **35** and **37** through the casing **31** wherein, when the tuning slugs have been adjusted to their final positions, the screws are inserted and lock the tuning slugs in position to prevent movement due to vibration or other causes.

Mounted on the exterior of the tubular casing **31** are the capacitor **17** and the coaxial connector **39**. The coaxial connector **39** has a center terminal **49** connected to the inner ends **50** of the helical windings **13** and **15**. The metal base **55** of the coaxial connector is mounted directly onto the casing **31** forming an electrical connection thereto. One terminal **51** of the capacitor **17** is also connected to the center terminal **49** of the coaxial connector **39**. The other end is connected to the casing **31**. Further, a wafer member **53** is mounted approximately midway between the tuning slugs **35** and **37** and fixedly retains the core **33** by snugly fitting between the core and the casing **31**. The wafer **53** may be formed by flowing a resilient plastic through a center hole and molding the plastic between two sleeves, each one slipped in from an end.

In operation, the foregoing apparatus is connected to an RF transmission line through the coaxial connector **39**. The tuning slugs **35** and **37** are adjusted so that the helical coils **13** and **15** resonate at the frequency of the undesired signals. By resonating at the frequency of the undesired signals they provide a high conductance path for these signals thereby shunting them. However, signals outside of the narrow band of resonant frequency signals are not subject to this high conductance pass and thereby continue to propagate down the transmission line's center conductor **11**.

It will be appreciated by those skilled in the art that the invention operates as an open-circuited one-fourth wave length shunt stub at its resonant frequencies. It also presents a high characteristic impedance to RF signals which results in a low insertion loss. In addition, it also provides apparatus having a high Q at resonant frequencies thereby presenting a maximum conductance path to signals at resonance and a much lower conductance path to off-resonant signals. Finally, the tuning is created by the mere variation of the dielectric properties between two conductors (the winding and the casing) in a conventional manner. Hence, the foregoing is a simple device for carrying out the method of the herein described invention.

In one embodiment of the invention attenuation of 25 to 27 db at the frequencies shunted has been obtained with practically 0 db insertion loss at the desired frequency where the desired frequency is within ± 8.5 percent of the rejected frequencies. It will be appreciated therefore that the invention comprises an improved method for filtering RF signals by passing a desired RF frequency signal and rejecting undesired RF signals closely spaced to the desired signal as well as a simple apparatus which is compact and lightweight, having a high Q and a low insertion loss, for carrying out said method.

Although the method of the invention has been illustrated as being carried out by one novel apparatus the method can also be practiced by other suitable apparatus. For example, conventional electronic networks could be used to shunt the signals of undesired frequency. Further, a quarter wave-length coaxial line connected in shunt relation to the coaxial transmission line will also shunt signals of undesired frequency.

The foregoing has set forth a preferred embodiment of the apparatus of the invention which performs the objects thereof. However, in light of the above teachings it is apparent that the invention may be practiced otherwise than as specifically described herein. For example, the apparatus of the invention is described as rejecting two frequencies, however, it is apparent that one frequency could be rejected by utilizing a core-tuning slug combination with only one helical winding thereon. Or the invention could be utilized to reject more than two frequencies by utilizing additional helical windings, cores

and tuning slugs. Consequently, both the method and apparatus of the invention may be practiced otherwise than as specifically described herein without departing from the spirit and scope of the invention as set forth in the appended claims.

What is claimed is:

1. Apparatus adopted for connection to a coaxial transmission line for rejecting a plurality of known undesired frequencies from said coaxial transmission line comprising a casing, said casing being a tubular metallic structure having a longitudinal axis; a core mounted in said casing, said core comprising a cylindrical dielectric structure having a longitudinal axis which coincides with the longitudinal axis of said casing when said core is mounted in said casing and wherein said core has a center section whereupon first and second helical windings are mounted, each of said windings beginning at the center of said center section and winding towards an end of said core; said first helical winding being wound about said core having the central end adapted for connection to said coaxial transmission line and the other end open circuited; said second helical winding wound about said core having the central end adapted for connection to said coaxial transmission line and the other end open circuited; a first axially adjustable tuning means for tuning said first helical winding to resonate one desired frequency; and a second axially adjustable tuning means for tuning said second helical winding to resonate at the other undesired frequency.

2. Apparatus as claimed in claim 1 wherein said core ends are threaded.

3. Apparatus as claimed in claim 2 wherein said first and second tuning means comprise a tubular structure of dielectric material having a longitudinal axis with an end opening along said longitudinal axis, said opening having a larger diameter end reducing to a smaller diameter with said smaller diameter tapped to fit the threads of said core ends.

4. Apparatus as claimed in claim 3 wherein said first and second tuning means have an outer diameter adapted to fit snugly within said casing when said tuning means is screwed onto said core ends.

5. Apparatus as claimed in claim 4 including a capacitor mounted on said casing having one terminal adapted for connection to a coaxial transmission line and a second terminal connected to said casing.

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333—82; 334—75; 325—477, 371

XGS-2816

NASA Case ~~No. 2816~~

Use Patent Title

~~METHOD AND APPARATUS FOR RF FILTERING~~

The invention relates to a novel method and apparatus for RF filtering wherein signals of undesired frequency are shunted from a coaxial transmission line.

The method of the invention comprises utilizing a very narrow bandpass filter tuned to resonate at the frequency of an undesired signal and connecting said filter in shunt relationship to the signal carrying conductor of a coaxial transmission line. The apparatus of the invention comprises a novel helically wound coaxial resonator connected as a shunt stub to a coaxial transmission line for the purpose of carrying out the method of the invention. Specifically, a pair of helically wound coils 13 and 15 are wound about a tubular core 33. The inner ends of the helical windings 13 and 15 are connected through a coaxial connector 39 to the signal carrying conductor of the transmission line. Screwed onto the ends of the tubular core are a pair of tuning cap members 35 and 37. The core and the tuning members are mounted inside of a casing 31 so that the longitudinal axes of the casing, core, and tuning cap members are coaxial. By varying the distance the cap members are displaced into the case, the resonant frequency of the helical windings can be varied. In this manner the helical windings are tuned to resonate at the frequency of the undesired signals whereby the undesired signals are shunted out. Further a capacitor 17 is mounted on the casing 31 having one terminal connected tothe signal carrying conductor of the coaxial line and the other end connected to the casing 31. The capacitor thereby shunts out residual inductance.

The novel features of this invention reside in the utilization of a novel coaxial resonant apparatus connected in a shunt relationship to a coaxial transmission line for shunting out undesired signals and allowing a desired signal to propagate down the transmission line to its utilization circuit. The invention has been illustrated as shunting signals of two frequencies, however, in a similar manner any number of signals at different frequencies may be shunted.

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